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DEPARTMENT OF COMMERCE
BUREAU OF STANDARDS
WASHINGTON

Letter
Circular
LC 92.

(November 14, 1923)

RADIO SIGNALS OF STANDARD FREQUENCY AND THEIR UTILIZATION.*

The Bureau of Standards at Washington, D.C. (station WWV) is conducting a series of transmissions of radio signals of known frequency to be used as a basis for adjusting and calibrating radio apparatus. These signals are transmitted approximately twice per month, and have been received and used satisfactorily in all parts of the United States east of the Mississippi River. Frequencies from 75 to 2000 kilocycles have been covered by past transmissions. The accuracy of the announced values of these signals is better than three-tenths of one per cent. Definite schedules giving the frequency to be transmitted and the exact time of the transmissions are announced in the newspapers, and also in the Radio Service Bulletin, a monthly periodical published by the Department of Commerce, for which subscriptions at the rate of 25 cents per year may be sent to the Superintendent of Documents, Government Printing Office, Washington, D.C.

General.-- The transmissions are by continuous-wave radio telegraphy. The schedule usually begins at 11:00 PM. The complete schedule usually consists of eight frequencies equally divided over the frequency range to be covered. At times, however, particular frequencies are transmitted such as those used in marine traffic without regard to the frequency range in which they appear. Each frequency is transmitted for eight minutes. During the first two minutes the general call is given and the frequency announced. During the following four minutes the letters WWV and a very long dash are transmitted very slowly, and during the remaining two minutes the frequency is again announced together with the next frequency to be transmitted. The wording used is somewhat as follows:

QST QST QST DE WWV WWV WWV -...- STANDARD FREQUENCY SIGNALS -...- FREQUENCY _____KC (Repeat for two minutes).

WWV ----- WWV ----- (Repeat for four minutes).

QST QST QST DE WWV WWV WWV FREQUENCY _____KC (Repeat for one minute).

QSY TO _____KC QSY TO ____KC .-.-. (Repeat for one minute)

There is then a four-minute interval during which time the transmitting set at WWV is adjusted for the next frequency to be transmitted.

*Prepared by H.J. Walls, Assistant Electrical Engineer.

A sample schedule is given below:

Sample Schedules of Standard Frequency Transmission from WWV.

Eastern Standard Time	Nov. 5 Frequency in Kilocycles*	Nov. 20 Frequency in Kilocycles*
11:00 to 11:08 PM	500 (600)*	150 (1999)*
11:12 to 11:20 PM	580 (517)	190 (1578)
11:24 to 11:32 PM	640 (468)	240 (1249)
11:36 to 11:44 PM	700 (428)	290 (1034)
11:48 to 11:56 PM	760 (394)	360 (833)
12:00 to 12:08 AM	833 (360)	430 (697)
12:12 to 12:20 AM	920 (326)	500 (600)
12:24 to 12:32 AM	1000 (300)	570 (526)

* Wave length in meters is given in parentheses.

The apparatus used in transmitting these signals consists of a 1-kw tube transmitting set which has been designed to maintain constant frequency regardless of antenna swinging and similar effects. For frequencies below 500 kilocycles a flat top T antenna having a height between antenna and counterpoise of about 130 feet is used, and for frequencies above 500 kilocycles a cage top T antenna having a height of about 70 feet above the counterpoise is used. For both antennas the antenna current is from 5 to 10 amperes.

Zero Beat Method of Reception.-- It is probable that the most important application of these signals is for calibrating wavemeters used for adjusting transmitting apparatus. There are several methods that may be employed for this purpose but only one, the zero beat method, is considered sufficiently accurate for precise work. This method consists of tuning a small electron-tube generating set to the same frequency as the incoming standard-frequency signal by means of beats in a radio receiving set between the output of the generating set and the incoming signal. When the frequency of the beat note is zero, the frequency of the generating set is then exactly the same as that of the incoming standard frequency signal. The wavemeter is then tuned to resonance with the generating set and since the frequency is known corresponding to that setting of the wavemeter, a point on the wavemeter calibration curve is determined. For information regarding the calibration of wavemeters see Circular of the Bureau of Standards No. 74 and Letter Circular of the Bureau of Standards No. 75. For information regarding the design of a portable short-wave wavemeter see Letter Circular of the Bureau of Standards No. 78.

In employing this method for wavemeter calibration the only apparatus necessary, in addition to a receiving set and wavemeter, is the small radio-frequency generating set or heterodyne. This generating set must produce sufficient radio-frequency current to satisfactorily operate the resonance indicating device of the

wavemeter. The generating set should be located as far away from the receiving set as possible since the strong signals produced by it may block the detector tube of the receiving set and render it inoperative.

If a non-regenerative receiving set is used it will be necessary to use the local generating set as a heterodyne when tuning in the signals from WWV. If a regenerative receiving set is available best results will probably be obtained if it is used in a generating (oscillating) condition when tuning in the signals of WWV. After picking up the signals, the receiving set should be adjusted for maximum regeneration without generation in order to obtain high sensitivity and selectivity, the local generating set being used as a heterodyne.

If the reaction of the wavemeter on the local generating set is sufficiently great to change its frequency, this will be evidenced by the production of beats and it will be necessary to loosen the coupling between the wavemeter and the generating set or retune the generating set. Little reaction by the wavemeter on the local generating set is to be expected if a sensitive device is used on the wavemeter as a resonance indicator. A sensitive thermogalvanometer or a hot-wire ammeter not requiring more than 100 milliamperes for full scale deflection is very satisfactory as an indicator. It will be advisable to keep the deflection down to below-half-scale deflection, since this can be read accurately and will permit the use of a looser coupling than the larger deflections.

Very precise measurements may be made with this method by using the following scheme. The local generator is adjusted to produce zero beat with the incoming signal and the wavemeter tuned to resonance as accurately as possible. If the frequency of the generating set is lowered, for example, 500 cycles, the resonance indicator reading will decrease. Then if the frequency is increased above zero beat by the same amount (500 cycles), the reading of the resonance indicator should increase to maximum as zero beat is passed and then decrease to the same value as was obtained at the frequency of 500 cycles below zero beat. In other words owing to the symmetrical shape of the resonance curve of a wavemeter the resonance indicator readings should be the same for frequencies above and below the resonance frequency by the same amount.

The ear cannot detect sounds whose frequency is less than about 16 cycles per second; it is, therefore, not possible to adjust the local generator to zero beat closer than about 32 cycles. On frequencies above 100 kilocycles this error can be neglected as it only amounts to about three hundredths of one per cent. at that frequency and decreases as the frequency increases.

Local Generating Set.-- Sufficient power can be obtained from a five-watt tube in a Hartley circuit, as shown in Fig. 1. Inductor "A" is a $3\frac{1}{2}$ inch tube of suitable insulating material about $4\frac{1}{2}$ inches long, wound with 55 turns of No. 16 B & S gauge double cotton covered copper wire with taps taken out from every fifth turn. This coil is used for frequencies from 500 to 2000 kilocycles. Inductor "B" consists of 200 turns of No. 22 B & S gauge double cotton covered copper wire on a tube about 5 3/4 inches in diameter and about 9 inches long. Taps are made on turns as shown in diagram. This coil is used for frequencies from 100 to 1000 kilocycles. The plate voltage may be secured from several $22\frac{1}{2}$ volt "B" batteries connected in series. Satisfactory operation can be obtained on voltages from about 100 to 400 volts. It is desirable to completely shield the generating set by placing it in a box lined with copper window screening which should be grounded. A long handle may be attached to the variable condenser control to obtain fine adjustment and reduce body capacity effects.

Resonance Click Method.-- Another method which is considered fairly satisfactory is the resonance click method or some of its variations. (See L.W. Austin, Journal Washington Academy of Science, 14, p.498, Aug. 19, 1918). In measuring the frequency of a signal by this method the wavemeter is coupled with the inductor of a regenerative receiving set in a generating (oscillating) condition which has been tuned to produce zero beat with the incoming signal. The setting of the wavemeter is varied until a click is heard in the telephones of the receiving set. This click is caused by the sudden absorption of power from the receiving set circuit by the wavemeter. If the coupling of the wavemeter to the receiving set is too close, the click will probably be heard with different settings of the wavemeter, depending upon whether the capacity of the wavemeter circuit is being increased or decreased. These clicks will approach each other as the coupling is loosened and a coupling will be found where only one click will be heard. This coupling should be used for the measurements.

This method can be used for measuring the frequency of telephone broadcasting stations or other stations (receiving set in a non-generating condition) by noting the sudden decrease of signal intensity as the wavemeter is tuned to the frequency of the incoming signal. To obtain accurate results it is necessary to use very loose coupling.

Calibration of Receiving Sets.-- These signals may also be used for approximate frequency calibration of receiving sets. For this purpose it is only necessary to plot a curve showing the relation between tuner setting and frequency or to mark the frequency corresponding to different settings directly on the dials. Care should be taken to note the settings of the dials of the coupling control and the regeneration control when the

calibration is made, and these same settings should be used when any reference is made to this calibration because a change in either coupling or regeneration may cause a change in frequency. Changing the detector tube will also affect the frequency calibration.

In calibrating a single-circuit receiving set it must be remembered that a change of antennas or any change in the antenna constants after the set has been calibrated will destroy the accuracy of the calibration. A two-circuit tuner may be used on different antennas with little change in accuracy since the secondary circuit calibration will remain practically constant with changes in antenna constants provided loose coupling is used between the primary and secondary circuits. The calibration of most receiving sets should be considered as only approximate since the calibration is changed by various adjustments and other factors in the use of the set.

Department of Commerce,
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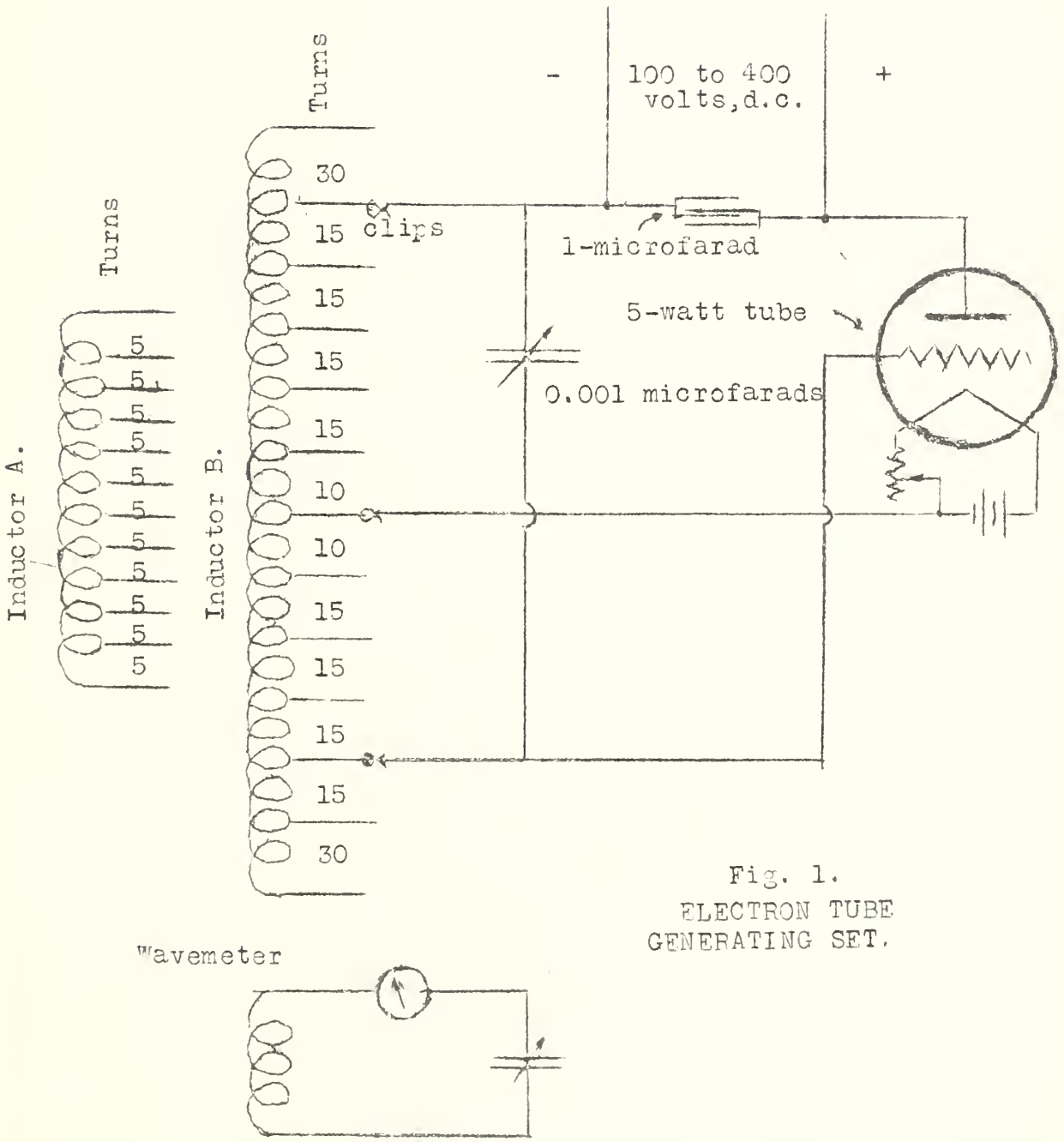

Fig. 1.
ELECTRON TUBE
GENERATING SET.